INTERLEAVED MULTI-BEAM ACQUISITION WAVEFORM PROVIDING CONCURRENT BEAM SELECTION, AUTOMATIC GAIN CONTROL (AGC) AND AUTOMATIC FREQUENCY CORRECTION (AFC)

BACKGROUND

[0001] 1. Field

[0002] Certain embodiments generally relate to communication systems and, in particular, may relate to millimeter wave (mmWave) communications.

[0003] 2. Description of the Related Art

[0004] A global bandwidth shortage facing wireless carriers has motivated the consideration of the underutilized millimeter wave (mmWave) frequency spectrum for future broadband cellular communication networks. mmWave (or extremely high frequency) generally refer to the frequency range between 30 and 300 gigahertz. This is the highest radio frequency band in practical use today. Radio waves in this band have wavelengths from ten to one millimeter, giving it the name millimeter band or millimeter wave.

[0005] mmWave systems will be characterized by higher propagation loss than lower frequencies. To combat this higher loss mmWave systems will employ antenna arrays with a large number of elements especially at the access point. The large arrays overcome the higher propagation loss by concentrating the energy in the best direction to the mobile through the use of narrow beams. Since mmWave systems will be characterized by high bandwidths, the analog to digital converters (ADCs) and digital to analog converters (DACs) will use extreme amounts of power. To minimize power consumption typically only a single ADC and DAC will be used for all antennas in one array meaning the beamforming will need to be done at radio frequency (RF). Besides data transmissions these narrow beams may need to be used for other transmissions such as for initial acquisition of timing and frequency. The use of these narrow beams at RF makes the use of existing acquisition methods difficult and inefficient, hence there is a need for an efficient method of initial acquisition for mmWave communications.

SUMMARY

[0006] One embodiment is directed to a method including transmitting, by an access point in a millimeter wave (mmWave) system, a first multi-beam sequence comprising a first burst type repeated on a defined pattern of antenna beams. The method may further include transmitting a second multi-beam sequence comprising a second burst type repeated on said defined pattern of antenna beams after an automatic frequency correction (AFC) interval.

[0007] Another embodiment is directed to an apparatus including at least one processor, and at least one memory comprising computer program code. The at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus at least to transmit a first multi-beam sequence comprising a first burst type repeated on a defined pattern of antenna beams, and transmit a second multi-beam sequence comprising a second burst type repeated on said defined pattern of antenna beams after an automatic frequency correction (AFC) interval.

[0008] Another embodiment is directed to a computer program embodied on a computer readable medium. The computer program is configured to control a processor to perform a process including transmitting, by an access point in a millimeter wave (mmWave) system, a first multi-beam sequence comprising a first burst type repeated on a defined pattern of antenna beams. The process may further include transmitting a second multi-beam sequence comprising a second burst type repeated on said defined pattern of antenna beams after an automatic frequency correction (AFC) interval.

[0009] Another embodiment is directed to a method including setting, by a user device, automatic gain control (AGC) in a receiver of the user device to a large gain. The method may further include detecting at least one acquisition burst in a multi-beam acquisition sequence, and detecting at least one corresponding automatic frequency correction (AFC) burst in a multi-beam AFC sequence one AFC interval later.

[0010] Another embodiment is directed to an apparatus including at least one processor, and at least one memory comprising computer program code. The at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus at least to set automatic gain control (AGC) in a receiver of the user device to a large gain, detect at least one acquisition burst in a multi-beam acquisition sequence, and detect at least one corresponding automatic frequency correction (AFC) burst in a multi-beam AFC sequence one AFC interval later.

[0011] Another embodiment is directed to a computer program embodied on a computer readable medium. The computer program is configured to control a processor to perform a process including setting automatic gain control (AGC) in a receiver of the user device to a large gain. The process may further include detecting at least one acquisition burst in a multi-beam acquisition sequence, and detecting at least one corresponding automatic frequency correction (AFC) burst in a multi-beam AFC sequence one AFC interval later.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] For proper understanding of the invention, reference should be made to the accompanying drawings, wherein:

[0013] FIG. **1** illustrates an example of a sector level sweep packet sequence;

[0014] FIG. **2** illustrates an example sector sweep frame format;

[0015] FIG. **3** illustrates an example of an mmWave system including APs and UDs, according to one embodiment;

[0016] FIG. **4** illustrates one example of an AP antenna set up with multiple arrays of different polarizations pointed in different directions, according to an embodiment;

[0017] FIG. **5** illustrates an example of a UD with two mmWave 2×2 antenna arrays, according to an embodiment;

[0018] FIG. **6** illustrates an example beam for a 4×4 array with 0.5 wavelength spacing in both azimuth and elevation directions, according to one embodiment;

[0019] FIG. **7** illustrates an example block diagram of a UD receiver, according to an embodiment;

[0020] FIG. **8** illustrates an example of a frame structure, according to an embodiment;

[0021] FIG. **9***a* illustrates an apparatus according to one embodiment;

[0022] FIG. **9***b* illustrates an apparatus according to another embodiment;

[0023] FIG. **10** illustrates an example of a flow diagram of a method according to one embodiment; and

[0024] FIG. **11** illustrates an example of a flow diagram of a method according to another embodiment.